Appendix D: References

1. **Suitor CJW, Gardner J, and Willett WC.** A comparison of food frequency and diet recall methods in studies of nutrient intake of low-income pregnant women. *J Am Diet Assoc* 89:1786-94, 1989.

2. **Wei EK, Gardner J, Field AE, Rosner BA, Colditz GA, and Suitor CJW.** Validity of a food frequency questionnaire in assessing nutrient intakes of low-income pregnant women. *Maternal and Child Health Journal* 3(4):241-6, 1999.

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A comparison of food frequency and diet recall methods in studies of nutrient intake of low-income pregnant women[1]

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Abstract The aim of this study was to develop a self-administered food frequency questionnaire for use with low-income pregnant women and to evaluate its performance in classifying women according to nutrient intake. Index nutrients used were energy, protein, calcium, iron, zinc, and vitamins A, B-6, and C. Two hundred ninety-five Massachusetts women, aged 14 to 43 years, participated in the field test of the questionnaire. A subset of 95 women provided three 24-hour diet recalls for use in comparative studies. Correlation coefficients between questionnaire and diet recall scores were adjusted for measurement error resulting from the limited number of 24-hour recalls per subject, and their confidence intervals were computed. When subjects with implausibly high energy scores (>4,500/day) were removed from the sample, reducing sample size by about 15%, correlation coefficients increased substantially (25% to 64%) for all nutrients except vitamin A. Adjusted correlation coefficients exceeded 0.5, excluding vitamin A ($r \sim 0.15$), and quintile comparisons indicated that the questionnaire would correctly identify a high proportion of the women having low intake of selected nutrients. We conclude that a self-administered questionnaire can provide useful data about individual recent intake of selected nutrients in a majority of English-speaking, low-income pregnant women, but that overestimation of food use may occur among up to 20% of this population. *J Am Diet Assoc 89:1786-1794, 1989.*

In 1985, the Committee on the Prevention of Low Birthweight identified nutrition as one of several areas needing attention in the nationwide effort to prevent low birth weight (1). Methods of dietary data collection that are efficient and valid could contribute to research efforts directed toward investigation of this health problem. The risk for having a low-birth-weight infant is higher among non-white mothers, teens, and mothers of low educational attainment than among the general population (1). Therefore, a dietary data collection method for use in the high-risk population needs to be suitable for a culturally diverse group of women, many of whom have limited literacy skills.

A commonly used dietary method in the assessment of maternal nutrition is a diet recall for a "typical day" or the previous 24-hour period (2-5). Although diet recalls do not require literacy on the part of the subject, they require a highly trained interviewer and can be time consuming. Furthermore, recalls for a single day are unlikely to be representative of the individual's mean daily nutrient intake because of wide day-to-day variations in kind and amount of food (6-11). Self-administered food frequency questionnaires (FFQs) hold potential for obtaining representative food and nutrient intake data in a more cost-effective manner from women who have basic reading skills.

Food frequency questionnaires have been developed and tested mainly for use in epidemiological research, that is, for identifying associations of dietary factors with diseases (12-17). Populations used for validation studies have included moderately to highly literate populations (13,15,17-19). FFQs validated with advantaged groups may not retain their validity when used for low-income pregnant women. However, many low-income women read at a fifth- or sixth-grade level or above (20) and thus should be able to complete a simple questionnaire.

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[3]The authors thank Soroya Diaz Briant, MS, and Lela Silverstein, MS, for translation services; Barbara Polhamus, MPH, RD, for help with arrangements for use of sites; Jelia Witschi, MS, RD, for monitoring of diet recall interviews and for expert guidance and support; Michael L. Feldstein, PhD, for consultation regarding study design and statistical analyses; Richard F. Suitor, PhD, for software development; Kim Paradis, MS, RD, for coding of diet recalls; Micheline Mondestin for assistance with data entry and checking; and the staff and patients at Chelsea-MGH Community Health Center and at Martha Eliot Health Center for their help during pilot testing. We extend special thanks to the staff and patients at Holyoke Prenatal Center, Harvard Street Neighborhood Health Center, and the Prenatal Center at Hyannis for their cooperation during field testing.

A food frequency questionnaire targeted toward pregnant women should collect data about recent intake and perform well in the common situation of changing appetite and food habits. Few studies (21,22) have involved FFQs designed to gather current dietary data, and those tested with prenatal and postnatal populations have been disappointing (22,23), despite use of interviewer-administered rather than self-administered questionnaires.

The purpose of this study was to develop and test a prenatal food frequency questionnaire (PFFQ) that could be self-administered by a majority of low-income patients during routine prenatal visits. We evaluated the PFFQ using the general strategy that follows.

Usability: We identified type and amount of assistance required in completing PFFQs, percent of completed PFFQs, frequency of technical errors, such as doubly marked or unmarked items, and percent of usable PFFQs. These characteristics were examined both during pretesting and field testing for all individuals.

Reproducibility of results after a short period: We correlated results obtained from the original PFFQ with those obtained from an identical PFFQ administered about 2 weeks later to a randomly chosen subsample.

Comparability of results with those obtained using a tested dietary data collection method: We did this for a randomly chosen subsample, in terms both of ranking individuals by nutrient intake and of comparing nutrient intake estimates. The comparison method used was 24-hour diet recalls for 3 nonconsecutive days.

The basic comparisons that were made are depicted in Figure 1; Figure 2 depicts the total study and highlights data sets and sample sizes used in this report.

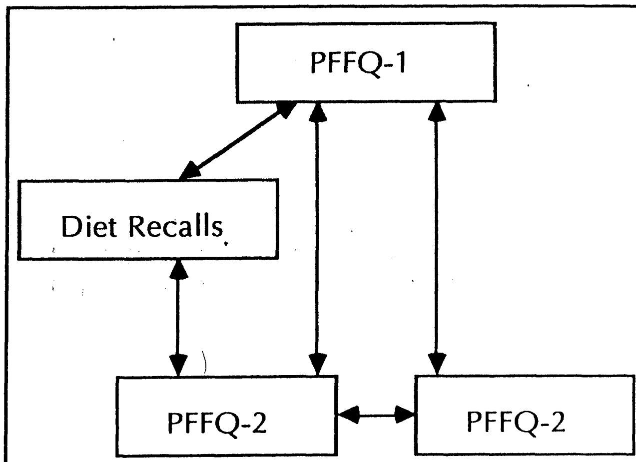

FIG. 1. *Comparisons made in evaluating the performance of the Prenatal Food Frequency Questionnaire, as denoted by the arrows. PFFQ-1 represents nutrient estimates made using the initial Prenatal Food Frequency Questionnaire, and PFFQ-2 represents those made using the identical follow-up questionnaire.*

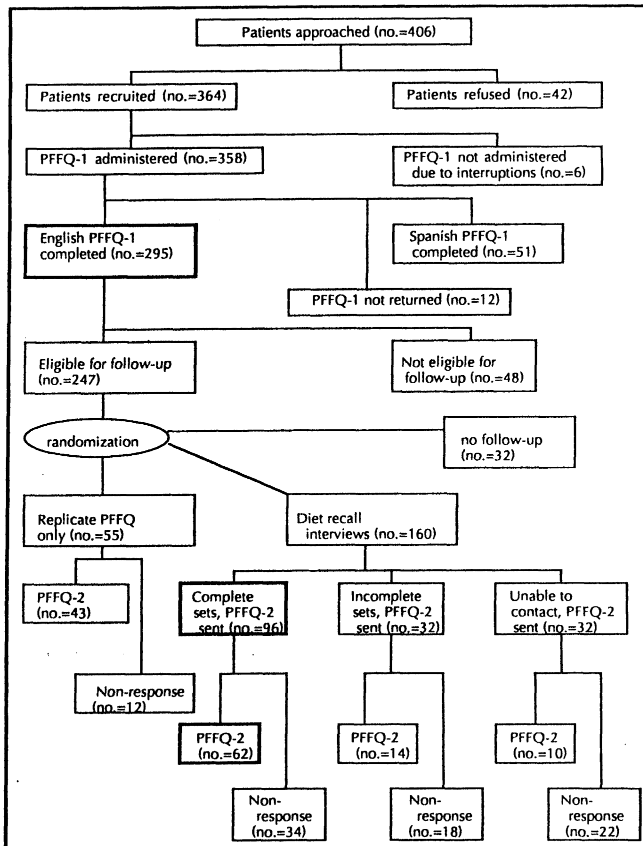

FIG. 2. *Elements of the total study and sample size. Data sets included in this report are enclosed in heavy black lines. PFFQ-1: initial Prenatal Food Frequency Questionnaire; PFFQ-2: PFFQ after an interval of about two weeks. Note: All women who provided diet recall interviews spoke English, but four completed Spanish PFFQs, and one did not return a PFFQ in either language.*

Materials and method

The Prenatal Food Frequency Questionnaire

The study instrument was an adaptation of a semi-quantitative food frequency questionnaire developed and tested by Willett et al. (13). The PFFQ was designed to categorize pregnant women by intake, over the past 4 weeks, of energy and selected nutrients of special concern during pregnancy. These nutrients included protein, calcium, iron, zinc, total vitamin A (from both plant and animal sources), and vitamins B-6 and C.

The PFFQ was pretested in two phases at prenatal clinics serving culturally diverse, low-income populations. During the second phase, we tested whether the women would be able to complete the PFFQ following simple written rather than oral directions. This was not well accepted by the participants and was quickly judged to be an unworkable approach. The entire pretest sample included 73 women.

After results of the pretests were analyzed, further adjustments were made in food items, wording, and format. A major change was the decision to delete most portion size information. Indicating portion size to the right of the food item appeared to increase reading time required by a substantial number of subjects who were reading word by word. Post-test questioning had revealed that such portion size information was not generally being used. We retained three items that did elicit responses, namely, asking whether usual portion size of milk, juice, and meat was small, medium, or large.

The only open-ended questions retained on the final PFFQ were for usual type of cold cereal and type of supplement, if any, used prior to pregnancy. The PFFQ included 90 foods and a total of 111 items.

For calculation purposes, portion sizes were assigned to each food item primarily on the basis of median portion size in grams reported for women 19 to 29 years of age in the Second National Health and Nutrition Examination Survey (24), as discussed by Block et al. (12). The same data set was used to assign gram weights for small and large portions of meat and fish (as a main dish) and juices. For milk, the gram weights of 4-, 8-, and 12-fl-oz portions were assigned to small, medium, and large portions. These were arbitrary decisions as it was impossible to determine median portion sizes prior to field testing.

The United States Department of Agriculture Nutrient Data Base for Standard Reference, Microcomputer Version, Release 5 (25), was used to obtain nutrient data per 100-gm portion for the food items on the PFFQ. Other data sources were used as necessary to supplement data on zinc, vitamin B-6, and a few ethnic foods (26-35). If the subject identified a brand name of cereal, the USDA food code was assigned; the default was Kellogg's® Corn Flakes.[4] Daily nutrient intakes from the PFFQ were computed by converting the midpoint of the frequency interval chosen to a mean daily frequency for each food item, multiplying this by the nutrient content for the assigned weight, and summing the value for all foods. The contributions of vitamin/mineral supplements are not included in this report.

The study population

The three sites used for recruiting subjects were receiving state funds for the delivery of prenatal services. This assured that the majority of subjects were from low-income populations. The site selection process was not random. Rather, consideration was given to the number of deliveries in the previous year, location, language barriers, willingness of the health center to serve as a site, and other factors related to the practicality of recruiting subjects. Sites differed in terms of census, routine procedures, and the ethnic groups served. Recruitment methods were designed to avoid selection bias and were tailored to the requirements of each site.

All pregnant women were eligible to provide baseline data unless they spoke neither English nor Spanish. After giving signed consent, women were asked orally to answer questions pertaining to demographics and selected behaviors, such as smoking. Women were eligible for follow-up if they spoke English and were no more than 8 months pregnant. These women were asked for information about how (i.e., by telephone or home visit) and when they were willing to be contacted. Those reporting that they had telephones in their homes were given a "2-D Food Portion Visual" (36) and were asked to keep it available in case they were contacted.

Medical record data regarding method of payment were used to estimate income. This made it possible to distinguish between women with family incomes ≤100% of the federal poverty level (Medicaid), women with family incomes between 100% and 200% of poverty (Healthy Start), and "other" women, including many without any insurance.

PFFQ administration

The recruiter explained and demonstrated how to complete the PFFQ, obtained feedback, and offered help in completing the questionnaire as needed. The usual time required for this process was 1½ to 3 minutes. It was generally impossible to measure the time required to complete the PFFQs because of constraints within the clinic setting, but it was estimated that most women completed it in less than 16 minutes.

With the use of subject lists and a system of random numbers, two follow-up groups were selected. The no recalls group was asked to complete the PFFQ a second time, about 2 weeks after the first. The recalls group was asked to provide three diet recall interviews and complete a duplicate PFFQ. Members of the recalls group were asked to complete a duplicate PFFQ regardless of the number of diet recall interviews actually completed.

Follow-up PFFQs (PFFQ-2) were mailed along with a short letter, a stamped return envelope, and a pencil; two were interviewer administered in the subject's home. In an attempt to improve PFFQ-2 response rates during the second half of the study, a token payment of $5 was offered at two of the sites to eligible participants. Payments were to be made after return of PFFQ-2.

Diet recall interviews

All diet recall interviews were conducted by CJWS using a slightly modified version of the method of Posner and Morgan (36). This method uses a standard procedure for asking subjects to name all foods, beverages, and supplements eaten the previous day (midnight to midnight), uses a tested visual aid (the 2-D Food Portion Visual) depicting food portion sizes in two dimensions, and probes for omitted items.

In general, subjects did not know in advance on what days the investigator would call. Telephone interviews were postponed if the subject needed a replacement of the visual aid since it was essential to the collection of standardized portion size data. The investigator brought the visual along on home visits. Interview quality was monitored periodically by a nutritionist experienced in dietary methodology. She reviewed a sample of diet recall forms as well as interviews taped with the subjects' permission.

When necessary, at least seven attempts were made to reach each interviewee for each of three rounds, unless the subject became ineligible because of premature delivery or otherwise unavailable for further follow-up.

Mean daily nutrient intake was estimated from sets of three 24-hour diet recalls using a Lotus 123 (37) worksheet that accessed the USDA Nutrient Data Base (the same database used for the PFFQ) by means of a developmental version of Blueprint.[5] Because the database was missing values for vitamin B-6 and zinc for approximately one-third of the food items, values from a number of sources (26-35) were used to supplement the missing data and to provide complete nutrient data for a number of commercial foods for which there were no comparable items in the USDA database. The few remaining missing values were inputed using values from similar foods.

[4]Kellogg Co., Battle Creek, MI.
[5]Lotus Development Corp., Cambridge, MA.

Statistical analyses

To minimize errors in coding and data entry, a series of steps were taken to independently verify and correct the data used.

Pearson product-moment and Spearman rank order coefficients were used to evaluate the reproducibility of PFFQ measurements. The same types of correlations were used in comparing nutrient intakes from PFFQs with those from diet recalls. Since both nutrient density (nutrient intake per 1,000 kcal) and absolute nutrient intake are of interest during the prenatal period, correlations were computed for both of these types of nutrient estimates.

Log base(e) transformed values were used in computations of correlation coefficients and variance components because most nutrient intake values were skewed to the right. Transformed values for a few nutrients retained some departure from normal distributions; therefore, Spearman rank order correlation coefficients were compared with Pearson coefficients. Since the results were essentially the same, only the latter are presented.

Mean nutrient intake estimates from a set of only three 24-hour diet recalls are known to include considerable measurement error resulting from high within-person day-to-day variation in food and nutrient intake. Sequence of interviews and day of the week effects are also potential sources of variation (6,38). Variance components were estimated for subject, interview sequence, day of the week effect (weekend vs. weekday), and error (within-person variation) using the PROC VARCOMP procedure of the Statistical Analysis System. The method described by Beaton et al. (6) and values obtained from the previously described analysis for within- and between-person variation were used to correct Pearson correlation coefficients for within-person variation. Ninety-five percent confidence limits for these corrected values were computed using formulas developed by Rosner and Willett (39). The size of the adjustment in the correlation coefficient depends on the relationship between within-person and between-person variation, as reflected by the intraclass correlation coefficients between days of 24-hour recalls. The higher the intraclass correlation, the higher the consistency in nutrient intake for the 3-day period and the smaller the adjustment made in the Pearson correlation between food frequency and diet recall intakes.

We used two methods to estimate percent agreement between PFFQ and diet recall intakes. In the first approach, the subjects' intakes from each dietary data collection method were grouped according to quintile. Percent agreement equalled the number jointly classified divided by the total number of diet recall scores in the quintile. We also determined agreement for the first quintile of the diet recall versus the first and second quintile of the PFFQ. Because of measurement error in the reference (diet recall sets), this first approach is likely to give spuriously low results.

In the second approach, we used correlation coefficients, adjusted for within-person variation in the 24-hour recalls, in conjunction with bivariate normal probability functions (40) to calculate joint classification by quintile. The functions were calculated using the approach suggested by Wang (41). In this case, percent agreement equalled the probability of the joint classification divided by 0.2.

Table 1. Demographic characteristics of women completing diet recalls and remainder of subjects eligible for follow-up

variable	*provided 3 diet recalls*	*remainder of eligible sample*	*total*
	←	no.	→
sample size[a]	93 to 95	172 to 180	265 to 275
	←	%	→
method of payment			
Medicaid[b]	61.3	59.3	60.0
Healthy Start[c]	24.7	28.5	27.2
other[d]	14.0	12.2	12.8
age group			
<18 years	13.7	13.3	13.5
education			
<10th grade	16.8	19.2	18.4
grades 10-11	18.9	24.3	22.4
high school graduate	50.5	39.5	43.4
>high school	13.7	16.9	15.8
race			
white	58.5	42.9	48.3
black	21.3	30.9	27.5
other (>99% Hispanic)	20.2	26.3	24.2
marital status			
single	49.5	60.0	56.4
married	35.8	28.9	31.3
other[e]	14.7	11.1	12.4
trimester			
first	10.5	14.2	12.9
second	42.1	39.2	40.2
third	47.4	46.6	46.9

[a]Because of missing data, the number of subjects in each group varies as indicated.
[b]Income ≤100% of federal poverty level.
[c]Income between 100% and 200% of federal poverty level.
[d]Self-pay or insurance through work.
[e]Separated, widowed, or divorced.

Results

Of the 406 women approached, 364 (90%) consented to take part in the study; 346 (85%) of the original sample responded to the initial PFFQ. This report concerns the 295 who completed the English version.

Eighty-four percent of the subjects who completed the English PFFQ were eligible for follow-up contacts. Of the 160 women randomly selected to provide diet recalls, 96 (60%) provided complete sets of three recalls. One or two diet recalls were obtained from an additional 31 women, leaving 20% completely lost to follow-up by interview. Sixteen subjects became unavailable during the follow-up period because of disconnected telephones, telephone to be used for messages only, travel, whereabouts unknown, or illness. One subject each refused to be interviewed a first, second, or third time.

The overall return rate for the second questionnaire (with or without intervening recalls) was 60%, having doubled from 40% to 80% for the no recalls group after arrangements were made for token payments.

Table 1 gives demographic characteristics for the

Table 2. Median and mean nutrient scores and standard deviations for diet recall sets and Prenatal Food Frequency Questionnaires (PFFQs)

nutrient	*total sample*				*values when caloric intake score less than 4,500*		
	diet recalls (no. = 95)	*PFFQ-1*[a] *(no. = 291)*	*PFFQ-2 only*[b] *(no. = 43)*	*PFFQ-2 with recalls*[c] *(no. = 76)*	*PFFQ-1 (no. = 240)*	*PFFQ-2 only (no. = 36)*	*PFFQ-2 with recalls (no. = 70)*
energy (kcal)							
median	2,125	2,695	2,052	2,317	2,386	1,736	2,274
mean	2,226 ± 709[d]	3,416 ± 2,711	3,010 ± 4,388	2,613 ± 1,429	2,518 ± 921	1,951 ± 1,050	2,269 ± 770
protein (gm)							
median	91	102	71	94	90	67	88
mean	91 ± 30	127 ± 105	117 ± 191	101 ± 50	95 ± 40	77 ± 51	90 ± 31
calcium (mg)							
median	1,169	1,498	1,018	1,300	1,247	887	1,247
mean	1,195 ± 495	1,663 ± 1,027	1,330 ± 1,176	1,393 ± 716	1,285 ± 733	1,017 ± 782	1,285 ± 619
iron (mg)							
median	13.7	16.9	13.5	14.4	14.9	12.01	13.98
mean	16.5 ± 9.2	21.8 ± 17.7	21.8 ± 29.6	18.0 ± 12.5	16.5 ± 9.0	13.90 ± 8.9	16.25 ± 11.0
zinc (mg)							
median	11.5	12.9	9.3	11.6	11.3	7.8	11.0
mean	12.0 ± 4.6	16.2 ± 13.6	14.6 ± 22.3	13.1 ± 6.7	12.1 ± 5.2	9.8 ± 6.4	11.8 ± 4.2
vitamin A (IU)							
median	4,769	11,738	9,246	9,900	9,887	7,591	9,497
mean	6,555 ± 5,461	17,492 ± 20,930	17,234 ± 23,897	12,062 ± 8,640	13,232 ± 12,419	10,925 ± 10,561	10,952 ± 7,100
vitamin B-6 (mg)							
median	1.75	2.51	1.83	2.04	2.24	1.55	2.01
mean	2.06 ± 1.16	3.21 ± 2.52	3.00 ± 4.47	2.46 ± 1.49	2.45 ± 1.25	1.91 ± 1.25	2.25 ± 1.31
vitamin C (mg)							
median	108	197	126	148	160	113	140
mean	134 ± 109	279 ± 245	230 ± 318	183 ± 147	211 ± 155	140 ± 110	158 ± 104

[a]PFFQ-1: Initial PFFQ, in English.
[b]PFFQ-2 only: Second PFFQ without any intervening diet recall interviews.
[c]PFFQ-2 with recalls: Second PFFQ after at least one diet recall interview.
[d]Mean ± standard deviation.

women completing the set of three diet recalls and for the total eligible sample. Women selected for follow-up but providing less than three recalls tended to be young, less educated, and more frequently non-white than those who provided complete data. Nonetheless, the sample included a very high proportion (86%) of women whose income was low, many of whom were non-white, unmarried, and had limited education. Group means for nutrient intakes did not differ significantly by the number of days of diet recalls provided. One of the diet recall sets was excluded because of implausible data and serious inconsistencies in reporting.

Women providing three diet recalls were compared on the basis of whether they had returned the second PFFQ. Those returning PFFQ-2 were unrepresentative of the original sample, being mainly white adults, high school graduates, and above the federal poverty level.

Usability

Missing responses or more than one response to a food item occurred infrequently. The mean number of these technical errors per questionnaire was 0.4; the median was zero. No PFFQs had to be excluded because of excess technical errors. About 93% of the PFFQs were completed independently. A priori, it was expected that a substantial percentage of the population would have difficulty with reading or interpreting the PFFQ and that caloric intakes in excess of 4,500 kcal per day would distinguish most of these individuals. Nearly 18% of the women completing initial PFFQs had estimated caloric intakes in excess of 4,500 kcal per day. These PFFQs were considered unusable, but we examined correlations with and without these suspect data.

Reproducibility

Mean and median absolute nutrient intakes and densities were higher for PFFQ-1 than for PFFQ-2 (Table 2). Absolute nutrient intakes for the PFFQs were greatly skewed toward higher values; therefore, the median was more representative than the mean as a measure of central tendency.

Correlation coefficients between absolute nutrient intakes estimated from PFFQ-1 and PFFQ-2 ranged between 0.6 and 0.9, with the lower values occurring among the recalls group (Table 3). When nutrient densities were

Table 3. Pearson product-moment correlation coefficients as an indicator of reproducibility of the PFFQ and of the comparability of results from the PFFQ with those from diet recall sets

nutrient log base (e)	*reproducibility*				*comparability with a standard method*					
	absolute value		*nutrient density*		*absolute nutrient value*			*nutrient density*		
	recalls group PFFQ-1[a] vs. PFFQ-2[b] (no. = 75)	*no recalls group PFFQ-1 vs. PFFQ-2 (no. = 43)*	*recalls group PFFQ-1[a] vs. PFFQ-2[b] (no. = 75)*	*no recalls group PFFQ-1 vs. PFFQ-2 (no. = 43)*	*PFFQ-2 vs. DR[c] (no. = 62)*	*PFFQ-1[d] vs. DR (no. = 87)*	*PFFQ-1[e] vs. DR (no. = 74)*	*PFFQ-2 vs. DR (no. = 62)*	*PFFQ-1 vs. DR (no. = 87)*	*PFFQ-1[e] vs. DR (no. = 74)*
energy	0.71	0.92	NA[f]	NA	0.41	0.23	0.47	NA	NA	NA
protein	0.56	0.87	0.41	0.49	0.33	0.22	0.44	0.32	0.44	0.47
calcium	0.68	0.80	0.64	0.52	0.52	0.46	0.60	0.52	0.57	0.51
iron	0.60	0.94	0.48	0.86	0.25	0.22	0.43	0.35	0.27	0.27
zinc	0.59	0.86	0.56	0.45	0.31	0.22	0.46	0.41	0.39	0.48
vitamin A	0.82	0.89	0.77	0.72	0.12	0.00	0.12	0.18	0.00	−0.02
vitamin B-6	0.65	0.91	0.59	0.82	0.30	0.21	0.42	0.36	0.36	0.35
vitamin C	0.65	0.83	0.63	0.61	0.34	0.42	0.56	0.40	0.51	0.53

[a]Initial administration of the Prenatal Food Frequency Questionnaire.
[b]Follow-up administration of the Prenatal Food Frequency Questionnaire, approximately 2 weeks after the first.
[c]DR: Mean nutrient estimates from set of 3 diet recalls.
[d]Values obtained using only subjects who completed PFFQ-2 are similar to those shown.
[e]Caloric intake estimated from PFFQ<4,500.
[f]NA = not applicable.

Table 4. Intraclass correlations (rI), observed Pearson correlations, adjusted correlations, and 95% confidence intervals (C.I.) between the first Prenatal Food Frequency Questionnaire and diet recall scores: Absolute values and nutrient densities (no. = 74)

energy and nutrients	*absolute nutrient scores*				*nutrient density scores*			
	rI	*observed correlation*	*adjusted correlation*	*95% C.I.*	*rI*	*observed correlation*	*adjusted correlation*	*95% C.I.*
energy	0.51	0.47	0.54	0.30, 0.71	NA[a]	NA	NA	
protein	0.41	0.44	0.54	0.27, 0.73	0.27	0.47	0.65	0.30, 0.84
calcium	0.48	0.60	0.71	0.48, 0.84	0.18	0.51	0.82	0.10, 0.97
iron	0.33	0.43	0.55	0.26, 0.76	0.11	0.27	0.53	−0.08, 0.85
zinc	0.41	0.46	0.56	0.30, 0.74	0.21	0.48	0.72	0.26, 0.92
vitamin A	0.36	0.12	0.15	−0.14, 0.42	0.21	−0.02	−0.03	−0.36, 0.30
vitamin B-6	0.43	0.42	0.50	0.24, 0.70	0.11	0.35	0.67	−0.07, 0.93
vitamin C	0.44	0.56	0.67	0.43, 0.82	0.33	0.53	0.69	0.39, 0.86

[a]NA = not applicable.

similarly compared, the two groups were more similar, and in some cases reproducibility was higher for the recalls group than for the no recalls group. Absolute nutrient intake was generally more reproducible than was nutrient density.

Comparability of PFFQ and diet recall results

Estimated total nutrient intakes were consistently higher for PFFQs than for diet recalls, as shown in Table 2. Observed correlation coefficients were relatively low (≤0.5) when subjects whose caloric intake exceeded 4,500 were included in the sample (Table 3). Correlation coefficients were generally higher between diet recalls and PFFQ-2, which covered the period that included the diet recalls, than between diet recalls and PFFQ-1. However, we used results from PFFQ-1 in further comparisons with diet recall intakes because we wanted to examine the food frequency questionnaire results using the least biased sample possible. We viewed this approach as a conservative one, which would tend to underestimate the PFFQ's performance.

When subjects whose caloric intakes exceeded 4,500 on PFFQ-1 were excluded, correlations of absolute nutrient intakes between PFFQ-1 and the diet recalls increased markedly (Table 3). Nutrient density estimates changed little when subjects with high caloric intakes were excluded. All correlations for vitamin A remained low.

Adjustments for measurement error due to within-person variation in 24-hour recalls

Random effects analysis of variance revealed no significant effect of weekday vs. weekend day or of the sequence of the diet recalls for any of the nutrients. Therefore, no adjustment was made for those variables. Intraclass correlation coefficients, which reflect agreement among diet recall days, are presented in Table 4, along with observed and adjusted Pearson correlation coefficients and 95% confidence limits for the latter. The relative adjustments

Table 5. Percent of individuals in the first or first and second quintile of the first Prenatal Food Frequency Questionnaire[a] who are in the first quintile for diet recalls: Observed and adjusted for measurement error

nutrient	*absolute nutrient intake*						*nutrient density*					
	observed				*adjusted[b]*		*observed*				*adjusted*	
	quintile 1		*quintiles 1 and 2*		*quintile 1*	*quintiles 1 and 2*	*quintile 1*		*quintiles 1 and 2*		*quintile 1*	*quintiles 1 and 2*
	no.	*%*	*no.*	←	*%*	→	*no.*	*%*	*no.*	←	*%*	→
energy	5/14[c]	36	7/14	50	46	71	NA[d]		NA		NA	NA
protein	4/14	29	6/14	43	45	73	4/14	29	10/14	71	53	79
calcium	7/13	54	10/13	77	57	83	6/14	43	11/14	79	66	91
iron	3/11	27	7/11	64	46	72	3/16	37	8/16	50	45	71
zinc	5/11	45	6/11	55	47	73	4/15	27	7/15	47	58	84
vitamin A	4/13	31	6/13	46	26	48	3/14	21	5/14	36	21	42
vitamin B-6	4/13	31	8/13	62	43	69	2/15	13	8/15	53	54	80
vitamin C	6/14	43	8/14	57	53	79	7/15	47	12/15	80	57	81

[a]Caloric score <4,500.
[b]Estimates made using bivariate normal distribution functions using the approach of Wang (41), with rho equal to adjusted correlation coefficients shown in Table 4.
[c]Denominators differ because of subjects who scored >4,500 kcal on PFFQ-1.
[d]NA = not applicable.

were greatest for iron and vitamin A, nutrients with considerable day-to-day variation as determined from our data.

We next calculated agreement for quintiles between the PFFQ and diet recalls, with and without correction for measurement error, excluding PFFQs with caloric intakes in excess of 4,500 (Table 5). The adjustment, which used the corrected rather than the observed correlation between the two methods, increased agreement by a range of 5% to 61%. Calcium was least and iron most affected. The highest agreement between PFFQ and diet recall methods was seen for calcium when adjusted values were used; more than 56% of the women in the lowest quintile for calcium according to the PFFQ were also in the lowest quintile according to the diet recalls; more than 82% of the women in the first quintile according to the diet recalls were in the lowest two quintiles according to the PFFQ.

Discussion

In choosing our dietary data collection comparison method, we ruled out the use of the diet history, a method which is similar in many ways to food frequency questionnaires and thus poses a problem of correlated errors. Furthermore, we found insufficient evidence that a diet history method has been satisfactorily validated with a low-income pregnant population. Although diet records would be least likely to be subject to the same errors as the PFFQ, diet recalls were considered more valid and practical in this case. Diet recalls require no reading or writing skills and minimal self-disciplined activity on the part of the subject. Although diet recalls have the disadvantage of dependence on memory, in common with the PFFQ, this effect may have been lessened somewhat by collection of data over time in the subjects' homes. Other household members were sometimes called upon or volunteered to help the subject make a complete recall. On the second or third interview, a few subjects provided additional information pertaining to the previous recall. That information was included in calculations of nutrient intake.

Methods for quantification of portion size were different for the diet recalls vs. the PFFQ, reducing the problem of correlated errors. Correlated errors, if present, are expected to increase observed correlation coefficients over actual values. If errors on PFFQs with implausibly high caloric intakes were correlated with errors on the diet recalls, discarding the implausible results would be expected to decrease correlation coefficients. In contrast, the opposite occurred.

Reasonably high correlations between two consecutive administrations of the PFFQ suggest that results are generally reproducible over a 2-week period. We expected results from the two questionnaires to be similar even if eating behaviors changed in the 2 weeks between the PFFQs because there was a 2-week overlap in the time covered. While it is possible that memory may have contributed to the reproducibility, this problem may have been reduced by the large number of items on the questionnaire, the 2-week interval, and the wording of the request for completion of the second PFFQ. (Subjects were told that we wanted to know whether what they had been eating was the same or different.) However, the relatively low response rate to the second PFFQ raises the possibility of bias. Furthermore, a tendency to overestimate or underestimate frequency of food use is likely to persist over this period and could have a major influence on correlations. Further testing of reproducibility alone would not eliminate the latter possibility.

The correlation for vitamin A between PFFQ-1 and PFFQ-2 illustrates the limits of reproducibility as a measure of questionnaire performance. Agreement between successive PFFQs for vitamin A was quite high (r>.8); however, correspondence between the PFFQ and diet recalls was negligible.

Correlation coefficients between the PFFQ and 3 days of diet recalls, unadjusted for within-person variation in recall data, were consistently lower than comparable values reported by Willett et al. (13), who used 28 days of diet recording per subject. Our unadjusted values suggested that the PFFQ did not perform at an acceptable level. Adjustment for measurement error narrowed the difference between the two studies. For example, the widely used and validated FFQ developed by Willett et al. reported correlations for absolute nutrient intakes for protein and for vitamins A, B-6, and C (without supplements) of 0.33, 0.26, 0.43, and 0.63, respectively. Our comparable corrected values were 0.54, 0.15, 0.50, and 0.66. Confidence intervals are wide, suggesting that a study with more subjects and more days of diet recall data would be desirable to confirm the results. The logistics and cost of such a study with a low-income pregnant population are, however, formidable.

Support for the validity of the adjustments made in this study comes from the work of Rosner and Willett (39). They used data from the Nurses Health Study to demonstrate that correlations based on small numbers of days of dietary intake are comparable to correlations based on 28 days' intake, after the former is adjusted for measurement error due to within-person variation in the recall data.

Poor correspondence between PFFQ and diet recall vitamin A intakes is not unexpected in view of the high day-to-day variation in vitamin A intake reported by other investigators (6,8,9). We noted that many women checked relatively frequent use (2 to 4 times per week) of a number of vitamin A-rich vegetables and several checked weekly use of liver, while relatively few women mentioned those foods during diet recall interviews. Mean vitamin A intake from our diet recalls (6,555 IU) is somewhat higher than that reported recently for non-pregnant 19- to 34-year-old women participating in the Food Stamp Program (42). The PFFQ appears to greatly overestimate vitamin A intake in general.

A high percentage of implausibly high caloric intakes has not been reported for other FFQs or populations. The high intakes resulted from checking high frequency of many food items rather than from problems with just a few items. This suggests a problem with questionnaire interpretation. Low literacy may have been closely linked to the questionable intakes but was not equivalent to educational attainment. Forty-nine percent of those with suspect data were high school graduates. Although single, very low-income, minority women were overrepresented among those having high estimated caloric intake, those were not distinguishing characteristics. Six of the 13 women who completed three diet recalls and scored >4,500 calories on PFFQ-1 fell in the lowest diet recall quintile for at least one nutrient. Thus a sizable percentage of the women for whom PFFQs were not usable were women whose nutrient intake was of particular interest.

Implications

Although the PFFQ used in this study needs some further simplification, it appears that this food frequency questionnaire can be useful in the collection of dietary intake data of low-income pregnant women. However, estimation of vitamin A intake appears to pose special problems with this population. We do not consider the PFFQ practical for interviewer administration in the clinic situation because of the amount of staff time that would be required. We have not tested whether respondents' answers would differ if the PFFQ were being used as a part of routine care (e.g., in the process of certification for the Supplemental Food Program for Women, Infants, and Children) rather than as part of a research project. Our results suggest that women who greatly overestimate their food intake on such a questionnaire may actually be at increased risk of having low nutrient intake. This result merits further investigation.

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Methodological Note

Validity of a Food Frequency Questionnaire in Assessing Nutrient Intakes of Low-Income Pregnant Women

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Objective: In 1989, a validation study of eight nutrients was performed on a modified food frequency questionnaire (FFQ) specifically designed for low-income pregnant women. The purpose of this study was to broaden the scope of the previous study by assessing the validity of the FFQ for 17 additional nutrients. *Methods:* The Pregnancy Food Frequency Questionnaire (PFFQ) was administered to a sample of 295 low-income, pregnant women aged 14–43 years living in Massachusetts. A randomly selected subsample of 101 women who provided at least one diet recall and reported intake of less than 4,500 calories were included in this analysis. *Results:* Mean intake of 25 nutrients as assessed by one administration of the PFFQ and up to three diet recalls collected over 1 month were similar. Unadjusted correlation coefficients between nutrient intake measured by diet recalls and the questionnaire ranged from .28 (carotene) to .61 (folate). After adjusting for energy intake the correlations ranged from .03 (B12) to .46 (folate). The correlations corrected for day-to-day variation were higher, ranging from .07 (B12) to .90 (zinc). The mean correlation was .47 and there were 54% over .40. *Conclusions:* A food frequency questionnaire for English-speaking, low-income, pregnant women can provide maternal and child health practitioners and researchers a valid estimate of diet across a wide range of nutrients.

KEY WORDS: Diet; pregnancy; low-income; diet assessment; validation; food frequency questionnaire.

INTRODUCTION

Several studies have looked at the use of a food frequency questionnaire (FFQ) in the context of pregnancy and/or among lower socioeconomic status women and found a reasonable degree of reproducibility and validity (1–4). For example, in 1994, Block presented the results of a validation of the Harvard FFQ tool among pregnant WIC participants (5) and in 1997, Kristal *et al.* validated their FFQ in low-income minority women (3). However, each author only reported the validity of their FFQ for six nutrients. In 1996, Brown *et al.* looked at the validity of a modified FFQ to assess pregnancy-related changes in intake of energy and 16 nutrients among primarily White and middle and upper income women (2).

In 1989, Suitor *et al.* (4) validated a version of the Harvard Service Food Frequency Questionnaire modified for low-income, pregnant women (PFFQ). It was designed to reflect recent intake and also validly assess any changes in appetite and/or food habits that can accompany pregnancy (4). With the exception of vitamin A, correlation coefficients between nutrients assessed by the PFFQ versus 24-hr recalls exceeded .50. That study limited its focus to energy

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WHAT HAVE YOU BEEN EATING LATELY?
DURING THE PAST 4 WEEKS, HOW OFTEN ON AVERAGE DID YOU EAT A SERVING OF EACH OF THE FOODS LISTED HERE?

PLEASE MARK ONLY ONE X FOR EACH FOOD	Never	per month	Per week			Per day			
		1-3	1	2-4	5-6	1	2-3	4-5	6+
Milk, any kind		X							
Ice cream or ice milk						X			
Yogurt, plain or flavored	X								
Cheese, plain or in sandwiches or casseroles									X
Pudding or custard				X					

Fig. 1. Sample of questions and layout of Pregnancy Food Frequency Questionnaire.

and seven nutrients: protein, calcium, iron, zinc, and vitamins A, B6, and C. Since many nutrients during pregnancy affect a woman's health and the health of her child, maternal and child health practitioners and researchers need a valid and comprehensive method for assessing diet for nutrition education, understanding predictors of diet during pregnancy, studying changes in diet during pregnancy, and characterizing associations between diet and pregnancy outcomes.

We extend the study by Suitor *et al.* by assessing the validity of the PFFQ for measuring intakes of energy, protein, total fat, saturated fat, polyunsaturated fat, monounsaturated fat, carbohydrate, calcium, iron, zinc, vitamin B6, vitamin C, vitamin E, vitamin B1, vitamin B2, vitamin B12, folate, sodium, potassium, magnesium, phosphorus, cholesterol, retinol, carotene, and vitamin A. Establishing the validity of the PFFQ across this wide range of nutrients increases its service and research applications for maternal and child health professionals.

METHODS

Study Population

Three sites in Massachusetts that received state funds to deliver prenatal services served as the recruitment sites. Of the 406 women approached, 364 agreed to participate, and 247 completed the English PFFQ and were eligible for follow-up. Of these 247, 160 were randomly selected to provide sets of three diet recalls. Of these 160 women, 118 completed at least one diet recall and the first PFFQ. Seventeen women who had implausibly high caloric values on the PFFQ (above 4,500) were excluded, leaving a total sample size of 101 for this analysis. Further detail regarding the study population has been described (4).

Prenatal Food Frequency Questionnaire

The prenatal food frequency questionnaire (PFFQ; see Fig. 1) is an adaptation of the food frequency questionnaire developed and evaluated by Willett *et al.* (6, 7). Unlike the original Willett FFQ, which is designed to measure intake over the last year, the PFFQ was designed to categorize pregnant women by intake over the past 4 weeks. Nutrients derived from the FFQ are estimated using the Harvard nutrient database. Intakes from vitamin and/or mineral supplements are not included in this report.

Diet Recall Interviews

One of the authors (C.W.S.), a registered dietitian, conducted all diet recall interviews. A modified version of the Posner and Morgan method was used to probe for food items and portions and includes a tested visual aid (the 2-D Food Portion Visual) (8). The nutrient calculations for the 24-hr recalls were performed with the Minnesota Nutrition Data System software, developed by the Nutrition Coordinating Center (NCC), University of Minnesota (Minneapolis, MN), Food Database Version 6A, Nutrient Database Version S21, as well as the USDA's Handbook No. 8, system release 11.

Statistical Analysis

All statistical analyses were performed using the Statistical Analysis System (Release 6.09; SAS Institute, Cary, NC). All nutrient intakes were log-transformed prior to analysis. Unadjusted and energy-adjusted Pearson correlations were calculated to compare nutrient intakes as assessed by the PFFQ and the diet recalls. Nutrient intakes from the diet recalls were calculated by averaging over the total number of diet recalls a woman completed. We also adjusted for energy intake and corrected for measurement error due to within-person and between-person variability (9–11). The energy-adjusted correlations were calculated from the residuals obtained by regressing each nutrient on the total calories (on the log scale) as measured by the PFFQ or diet recalls (10).

Unlike the statistical analyses used by Suitor *et al.* to correct for measurement error, we used a new pairwise estimator (12). This new method allowed us to include women who completed less than three diet recalls.

Intakes as measured by the two methods were divided into quartiles and then cross-classified. Comparing extreme quartiles gives an estimate of the degree of misclassification (i.e., highest quartile by diet recalls misclassified into lowest quartile by PFFQ).

Table I. Demographic Characteristics of Total Sample of Low-Income Pregnant Women (N = 101)

	%
Method of payment	
Medicaid[a]	54.4
Healthy start[b]	33.3
Other[c]	12.2
Age group	
<18 years	12.9
≥18 years	87.1
Education	
<10th grade	11
Grades 10–11	24.8
High school graduate	47.5
>High school	16.7
Race	
White	63.4
Black	18.8
Hispanic	17.8
Marital status	
Single	46.5
Married	39.6
Other[d]	13.9
Trimester[e]	
First	54.4
Second	26.5
Third	19.1

[a]Income less than or equal to 100% of federal poverty level.
[b]Income between 100% and 200% of federal poverty level.
[c]Self-pay or insurance through work.
[d]Separated, widowed, or divorced.
[e]Due to missing data, the sample size for trimester is n = 90.

RESULTS

Table I presents demographic characteristics on the sample of women used in this analysis. No significant differences existed between our study population and the original study population. Table II shows means and medians for average daily nutrient intakes from the diet recalls and from the PFFQ for the 101 women included in this analysis. Except for saturated fat, cholesterol, and sodium, intake as measured by the PFFQ tended to be higher than that measured by the diet recalls. Overall, 17 of 26 median values for the unadjusted nutrients as measured by the PFFQ were within 10% of the diet recall values.

The Pearson correlations between the two dietary assessment methods are shown in Table III. After adjustment for energy intake and measurement error, the correlations ranged from .07 to .90. The mean correlation across all of the nutrients was .47.

Based on our cross-classification of nutrient intakes as measured by the two methods (data not shown), the highest agreement for being in the lowest quartile by both instruments was 55% (vitamin B2). The highest percentage agreement for being in the highest quartile by both instruments was 45% (vitamins C, B12 and folate). Saturated and polyunsaturated fat were the most misclassified. Twenty-five percent of individuals classified in the highest quintile by the diet records for these two fat types were in the lowest quintile according to the PFFQ.

DISCUSSION

After correcting for energy intake and measurement error, the mean correlation of .47 between the

Table II. Mean ± SD, Median, and Median Difference of Daily Intakes Estimated by the Average of One, Two, or Three Diet Recalls and the Prenatal Food Frequency Questionnaire (N = 101)[a]

Nutrient	24-Hr recall		PFFQ		Median difference
	Mean ± SD	Median	Mean ± SD	Median	
Calories	2276.6 ± 782.2	2267.8	2561.5 ± 893.9	2448.7	138.98
Total fat (g)	95.2 ± 40.0	93.8	96.2 ± 35.8	95.3	2.39
Saturated fat (g)	38.9 ± 18.6	36.0	35.0 ± 14.1	33.4	−1.37
Polyunsaturated fat (g)	14.9 ± 7.0	15.4	17.8 ± 7.6	17.4	1.30
Monounsaturated fat (g)	34.3 ± 14.3	32.9	35.9 ± 13.5	35.1	2.26
Carbohydrate (g)	268.6 ± 99.5	262.1	335.6 ± 134.4	308.6	41.63
Protein (g)	92.6 ± 34.7	91.6	99.5 ± 38.3	98.0	10.66
Vitamin C (mg)	138.6 ± 122.9	97.9	244.9 ± 162.3	192.8	86.26
Vitamin E (mg)	10.2 ± 11.5	7.1	11.6 ± 13.4	8.3	0.22
Vitamin B1 (mg)	2.0 ± 1.0	1.8	2.3 ± 1.1	2.2	0.16
Vitamin B2 (mg)	2.7 ± 1.3	2.6	3.2 ± 1.5	2.9	0.50
Vitamin B6 (mg)	2.0 ± 1.1	1.7	2.8 ± 1.4	2.5	0.58
Vitamin B12 (mcg),	7.5 ± 6.2	5.8	12.1 ± 12.4	8.6	2.02
Folate (mcg)	317.8 ± 219.9	246.0	461.9 ± 296.2	366.1	112.77
Zinc (mg)	13.1 ± 7.5	11.2	15.2 ± 8.3	14.0	1.87
Sodium (mg)	3704.9 ± 1466.9	3481.6	3357.5 ± 1402.1	3265.2	−217.90
Potassium (mg)	3191.9 ± 1404.2	2952.4	4124.6 ± 2004.8	3898.6	759.63
Calcium (mg)	1268.0 ± 643.1	1251.4	1559.0 ± 810.8	1524.7	239.95
Iron (mg)	16.9 ± 11.0	13.6	17.1 ± 9.4	15.2	1.39
Magnesium (mg)	304.9 ± 125.6	289.8	354.1 ± 153.6	339.2	43.88
Phosphorous (mg)	1646.2 ± 665.2	1678.9	1946.7 ± 816.1	1802.8	297.81
Cholesterol (mg)	411.2 ± 228.2	364.5	337.5 ± 152.2	309.8	−47.78
Retinol (IU)	2452.4 ± 1947.5	1935.4	5040.6 ± 4217.6	3988.2	1838.91
Carotene (IU)	3852.7 ± 5009.8	2076.4	7423.1 ± 6195.4	5825.8	3119.10
Vitamin A (IU)	6305.2 ± 5708.4	4653.9	12463.7 ± 8668.4	10591.3	4876.85

[a]All subjects who reported >4,500 calories on the PFFQ were excluded from this analysis.

PFFQ and diet recalls was similar to the mean correlations found in validations of widely used FFQs and other epidemiologic measurements in populations (5–7, 9, 13–16). For example, the Nurses' Health Study and the Health Professionals Follow-up Study reported mean correlations of .44 (6) and .60 (7), respectively.

Several nutrients (saturated fat, polyunsaturated fat, folate, zinc, sodium, and iron) had wide correlation coefficient confidence intervals. These wide confidence intervals, which occasionally crossed zero, are consistent with at least one other study in a low-income population and likely reflect high day-to-day variability due to factors such as chronic or sporadic food insufficiencies (17). These results suggest that more subjects and more days of diet recall information would be required to confirm the precision of our estimates for these particular nutrients. Although the correlation estimates for these few nutrients were imprecise, the PFFQ provides a reasonably accurate measure for the majority of the nutrients investigated.

When we compared correlations between our study and the original study across the original eight nutrients, our correlations were noticeably higher for protein (.63 vs. .44), iron (.68 vs. .43), zinc (.90 vs. .46), and vitamin B6 (.620 vs. .42). Our correlations were very slightly lower than those reported by Suitor *et al.* for calcium (.55 vs. .60), vitamin C (.54 vs. .56) and energy (.42 vs. .47). For vitamin A the correlation was exactly the same (.12). With the exception of zinc, iron, and vitamin A, which had extremely wide confidence intervals, our results confirm the previous results of Suitor *et al.* in five of the original eight nutrients.

A potential limitation of the PFFQ is that is does not give absolute or exact intakes due to the short list of food items. The results of our cross-classification showed that extreme misclassification of nutrient intakes was rare. This suggests that the PFFQ can appropriately rank individuals relative to one another even if absolute intakes may not be precise. This should be adequate in settings that only require the ability to detect extreme nutrient intakes or to estimate intake on a population level.

Another limitation of the PFFQ was its ability

Table III. Pearson Correlation Coefficients between PFFQ and Average of One, Two, or Three 24-Hr Recalls: Unadjusted, Energy-Adjusted, and Corrected for Measurement Error ($N = 101$)

Energy and nutrients	Unadjusted r	Adjusted r	Deattenuated r	95% CI for deattenuated r
Calories	0.42			
Total fat (g)	0.33	0.24	0.30	(0.02, 0.54)
Saturated fat (g)	0.32	0.14	0.27	(−0.01, 0.52)
Polyunsaturated fat (g)	0.35	0.21	0.20	(−0.09, 0.45)
Monounsaturated fat (g)	0.30	0.28	0.40	(0.07, 0.66)
Carbohydrate (g)	0.44	0.28	0.30	(0.03, 0.53)
Protein (g)	0.49	0.44	0.63	(0.26, 0.84)
Vitamin C (mg)	0.41	0.36	0.54	(0.26, 0.73)
Vitamin E (mg)	0.46	0.39	0.80	(−0.45, 0.99)
Vitamin B1 (mg)	0.46	0.44	0.76	(0.08, 0.96)
Vitamin B2 (mg)	0.49	0.38	0.60	(0.20, 0.83)
Vitamin B6 (mg)	0.46	0.35	0.62	(0.25, 0.83)
Vitamin B12 (mcg)	0.35	0.03	0.07	(−0.42, 0.53)
Folate (mcg)	0.61	0.46	0.86	(−0.16, 0.99)
Zinc (mg)	0.50	0.45	0.90	(−0.91, 1.00)
Sodium (mg)	0.37	0.09	0.35	(−0.09, 0.68)
Potassium (mg)	0.58	0.27	0.38	(0.13, 0.59)
Calcium (mg)	0.57	0.39	0.55	(0.26, 0.75)
Iron (mg)	0.37	0.36	0.68	(−0.03, 0.93)
Magnesium (mg)	0.60	0.33	0.46	(0.20, 0.66)
Phosphorous (mg)	0.56	0.43	0.57	(0.28, 0.77)
Cholesterol (mg)	0.30	0.32	0.48	(0.11, 0.73)
Retinol (IU)	0.41	0.19	0.31	(0.03, 0.54)
Carotene (IU)	0.28	0.08	0.15	(−0.27, 0.52)
Vitamin A (IU)	0.38	0.07	0.12	(−0.25, 0.46)

to assess vitamin A intake. However, low correlations for vitamin A are commonly observed in nonpregnant adult populations (9). As previously reported by Suitor *et al.*, the low correlation for vitamin A might be explained by the inconsistency of reporting between vitamin A-rich vegetables and liver on the PFFQ and relatively infrequent reports of these foods in the diet recalls (4). Thus, any results for intakes of vitamin A assessed by the PFFQ should be scrutinized before conclusions are drawn.

Although vitamins and supplements were not included in both this study and the original study, the high number of supplement users among WIC participants suggests that future research should investigate their contribution to nutrient intakes.

The exclusion of 14% of our sample due to PFFQ caloric intake estimates above 4,500 suggests that a fairly significant proportion of the women were unable to complete the PFFQ accurately. Similarly in the original work by Suitor *et al.*, nearly 18% of women reported caloric intakes above 4,500. Future work should investigate methods to identify women who are unable to complete the PFFQ adequately.

This work supports the results of a previous validation of the PFFQ. However, we were able to establish the usefulness of the PFFQ for assessing a wider range of nutrients, thereby increasing its potential applications in current and future maternal and child health research and service settings. The PFFQ is a valuable tool for maternal and child health researchers' investigations, including the effects of diet during pregnancy on birth outcomes and the health outcomes of the child. Expanded uses also include service program planning, nutrition education and interventions, and nutritional surveillance.

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Methodological Note

Validation of a Food Frequency Questionnaire in Native American and Caucasian Children 1 to 5 Years of Age

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Objective: To assess the validity of the Harvard Service Food Frequency Questionnaire (HFFQ) in the diet assessment of Native American and Caucasian children 1 to 5 years of age participating in the North Dakota WIC program. *Methods:* The 84-item HFFQ was administered twice to the parent or guardian of 131 Native American and 102 Caucasian children ages 1 to 5 years (total $n = 233$), first at the child's routine WIC visit and then following the completion of three 24-hr dietary recalls taken over approximately 1 month. Average nutrient intakes from the three 24-hr dietary recalls were compared to average nutrient intakes from the HFFQs by calculating Pearson correlation coefficients and adjusting for energy intake and within person variation. *Results:* Correlation coefficients ranged from 0.26 for dietary fiber to 0.63 for magnesium. The average correlation was 0.52, similar to that found in validation studies among adolescents and adults. The following nutrients had correlations of 0.50 or greater: carbohydrate, sucrose, total fat, vitamin C, vitamin E, vitamin B1, vitamin B2, niacin, folate, vitamin B6, calcium, magnesium, and iron. *Conclusions:* The HFFQ is a simple self-administered questionnaire completed by the child's parent or guardian and is useful in assessing the diets of Native American and Caucasian children. It may also provide important nutritional information about this age group for future program planning, research, education, and intervention purposes.

KEY WORDS: Nutrition; diet assessment; children; low-income; validation; Harvard Service Food Frequency Questionnaire.

INTRODUCTION

Very few studies have measured the validity and/or reliability of food frequency questionnaires in assessing the dietary patterns of children ages 1 to 5 years. Two studies examined the performance of modified versions of the Willett food frequency questionnaire (1) against a number of 24-hr dietary recalls. Trieber and colleagues reported a mean correlation of 0.67 (range = 0.42 to 0.83) (2) among children aged 3 to 5 years, while Stein and colleagues reported an average correlation between 0.30 and 0.40 for preschool children (ages 44 to 60 months at baseline) (3).

In 1994 Block presented the results from a USDA funded study to validate two food frequency tools: one developed by Block and colleagues and the Women's and Children's versions of the Harvard Service Food Frequency Questionnaire (HFFQ) (4). The performance of the Children's HFFQ was compared to "true" dietary intake as assessed by three 24-hr dietary recalls administered by telephone. After

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excluding outliers, the average correlation for children aged 12 months through 4.9 years was 0.25 for both the HFFQ and the Block FFQ. One of the limitations of this study was that dietary intake was measured over two different time periods. The HFFQ asks about food intake over the past 4 weeks while the 24-hr dietary recalls were collected over a time period ranging from 2 to 5 weeks. The current study provides a more comparable estimate of dietary intake over a 4-week period because the 24-hr dietary recalls were consistently collected over the 4 weeks following the first HFFQ.

The HFFQ has been validated for use in Maternal and Child Health clinics to assess the diets of low-income pregnant, lactating and nonpregnant or nonlactating women (5, 6). The present study compliments past and recent research on the reproducibility and validity of the Willett and Harvard Service Food Frequency questionnaires. In addition, due to the lack of available validated diet assessment tools for use in assessing the diet of multi-cultural, low-income children aged 1 to 5 years old, the current study adds to the search for useful methods of diet assessment for use in service settings targeting child nutrition. Nutritional information about this age group would be invaluable for local, state, or national program planning, research, education, and intervention purposes. The aim of the current study was to address the validity of the 84 item HFFQ in the diet assessment of Native American and Caucasian children ages 1 to 5 years participating in the North Dakota WIC program. Validity is assessed by comparing the nutrient values from the HFFQ against the average nutrient values of three 24-hr diet recalls.

METHODS

Development of the HFFQ

The Harvard Service Food Frequency Questionnaire was developed to assess the diets of low-income women and was subsequently modified in 1991 (7) as a dietary assessment tool for children and youth. The 1991 adaptation for children (The Children's HFFQ) is a modified version of a semi-quantitative food frequency questionnaire developed and validated for use among adults by Willett *et al.* (1). It is a total of 103 items, including 84 foods and 19 questions about food habits, supplements, and services. (See Fig. 1 for sample questions and layout). It is completed by the child's parent or guardian and is available in both a paper and computer direct entry format. The paper format was used in this study. Portion sizes used with the HFFQ for calculation of nutrient intake are derived from national data (CSFII) and are age appropriate.

Recruitment of Children for the Validation Study

We sequentially recruited a sample of parents and guardians (n = 277) with children ages 1 to 5 years (n = 450) appearing in North Dakota WIC clinics who agreed to participate in the project after reviewing an invitation letter that described the study. Each parent or guardian signed a consent form at the child's routine WIC visit, confirming their willingness to participate. 189 parents had 1 child in the study and 50 parents had 2 or more children participating (2 children, n = 44; 3 children, n = 6). At the completion of the data collection our sample included a total of 300 children ages 1 to 5 years. There were 172 Native American (57%) and 128 Caucasian (43%) children. Approximately one half of the children were 1 through 2 years old (12 through 35 months; n = 158, 53%) and one half were 3 to 5 years old (36 to 60 months; n = 142, 47%).

Collection of HFFQs and 24-hr Dietary Recalls

The HFFQ was completed by the child's parent or guardian for the first time at a routine WIC visit. Following the visit, three 24-hr dietary recalls were completed over the subsequent month. The three recalls were completed approximately every 7 to 10 days. In general, two recalls were taken on weekdays and one recall on the weekend to capture differences in eating habits by day of the week. The exact schedule was not known by the parent participants, only that there would be three recalls. The HFFQ was then administered a second time after completion of the three 24-hr recalls.

The recalls were administered by telephone or in person (some of the participants did not have telephones, so the dietitians traveled to their homes). Each child's intake was entered directly into the computer by a registered dietitian working for North Dakota WIC and familiar with this population. The dietitians participated in a one-half day training session led by a research nutritionist to become familiar with the Minnesota Nutrient Data System (MNDS). The

Children's Nutrition Questionnaire
What Has Your Child Been Eating Lately?
During the past 4 weeks, how often did your child eat a serving of each of the foods listed here?
Mark only one X for each food

	Last 4 weeks		Each week			Each day			
Number of times	0	1-3	1	2-4	5-6	1	2-3	4-5	6+
Milk						X			
Hot Chocolate	X								
Cheese, plain or in sandwiches				X					
Yogurt	X								
Ice cream		X							
	0	1	2	3	4	5	6	7	8

Fig. 1. Sample of questions and layout of Harvard Service Food Frequency Questionnaire.

average dietary recall of the preceding 24 hr took about 20 min to record.

Data were checked by a local study coordinator, also a registered dietitian, in North Dakota and then sent to our offices in Boston where they were again checked for plausible intake by the supervising research nutritionist. Nutrient values were derived from each of the 3 days of recall and the average calculated. Nutrients derived from the HFFQ are estimated using the Harvard nutrient database. The foundation of the database is the U.S. Department of Agriculture Nutrient Database for Standard Reference. Release 10 and 11, Washington DC 1993 (8) and 1996 (9), with additional information from McCance and Widdowson's *The Composition of Foods* (4th and 5th editions) (10, 11), journals, and manufacturers.

The nutrients calculations for the 24-hr recalls were performed with the Minnesota Nutrition Data System software, developed by the Nutrition Coordinating Center (NCC), University of Minnesota (Minneapolis, MN), Food Database Version 6A, Nutrient Database Version S21. If an analytic value is not available for a nutrient in a food, NCC calculates the value on the basis of the nutrient content of other nutrients in the foods. A missing value is allowed in the following cases: if the value is believed to be negligible, the food is usually eaten in a very small amount, it is not known whether the nutrient exists in the food at all, or there is no way to estimate the value because the food is unlike any other.

Statistical Analysis

All statistical analyses were performed with the Statistical Analysis System (Release 6.09; SAS Institute, Cary, NC). Average nutrient intake from the three 24-hr dietary recalls was compared to average nutrient intake of the combined HFFQs. We calculated Pearson correlation coefficients and adjusted for energy intake and within-person variation as assessed from the 24-hr recalls (12, 13). We excluded children who consumed more than 3,500 calories per day or less than 500 calories per day (14 children) and randomly selected one child from each family with more than one child participating in the study from the analysis, leaving 233 children in the data set for evaluation of validity. The data presented includes multivitamin supplements in the nutrient analysis (26% of children reported using multivitamin supplements).

RESULTS

Of the 277 parents who agreed to have their child(ren) participate (2 parents invited to participate declined due to plans to move), 239 (86%) completed both HFFQs and all three dietary recalls about their child(ren)'s eating habits. Reasons for nonparticipation included moving, disconnected phone, client unavailable to participate (never home and/or unreachable), and refusal to participate after first 24-hr recall. The sample, before exclusions, included a total of 300 of the 450 (67%) children originally invited to join the study. After excluding children who consumed more than 3,500 calories per day or less than 500 calories per day and multiple siblings in the same family our final sample included 233 children aged 1 to 5 years. We examined data for 131 (56%) Native American and 102 (44%) Caucasian children and 129 children aged 1 through 2 years (55%) and 104 children aged 3 to 5 years (45%).

We examined 20 nutrients defined *a priori* including, protein, carbohydrate, total fat, sucrose, dietary fiber, calcium, iron, vitamin C, vitamin B1, vitamin B2, niacin, vitamin B6, folate, vitamin B12, vitamin A, vitamin E, magnesium, zinc, cholesterol, and total energy intake. When we compared the HFFQ to the 24-hr recalls the mean nutrient intakes estimated by each tool varied by less than 10% (see Table I). For example, the mean intake of calcium was 1016 mg when estimated by the HFFQ and 1087 mg when estimated by the 24-hr diet recalls. These values are strikingly similar given the possibility of over- and underestimation of food intakes when using a food frequency questionnaire (12).

Correlation coefficients between the dietary intake assessed by the two methods ranged from 0.26 for fiber to 0.63 for magnesium. All but three nutrients (protein, dietary fiber and zinc) had correlations of 0.47 or higher. After adjusting for energy intake and within-person variation the average correlation was 0.52 (see Table I).

DISCUSSION

These data show strong evidence that the HFFQ for children has validity comparable to that observed among adults reporting their own diet over the preceding year. We have observed average correlations of 0.47 in our studies of the HFFQ for pregnant women (5, 6), 0.54 in our studies of the Youth Adolescent Questionnaire (14), 0.60 in our studies among health professionals (15), and 0.44 and 0.61 in our studies of the Nurses' Health Study Food Frequency Questionnaire (16, 17).

The current study strengthens the existing research, demonstrating that past dietary intake of children aged 1 to 5 years can be measured reasonably well with a food frequency questionnaire completed by the child's parent or guardian. Moreover, two of the previous similar studies of diet assessment in children under age 5 years estimated the validity of modified versions of the Willett FFQ while the Block study examined the validity of the HFFQ for children which was also derived from the Willett FFQ. The HFFQ for children has since been modified and implemented in three state WIC programs for dietary assessment of clients in Massachusetts, Missouri, and North Dakota. The North Dakota WIC program has been using the HFFQ since 1993, therefore the providers are very familiar with the form and its administration. This familiarity makes data collection run more smoothly than if the providers had to familiarize themselves with a new tool while recruiting participants and collecting data. The forms used by Treiber *et al.* and Stein *et al.* were modified and administered especially for the purpose of their study (2, 3).

Our participation rate was good with 86% of the parents recruited to participate completing the entire study. This high participation rate reduces the potential for bias in our estimates of validity. Of the 38 parents who left the study, 29% (n = 11) had more than 1 child participating in the study; however, 50 women (20%) with more than one child completed the study through to the end. To eliminate the potential bias created by parent's completing forms for more than one child we excluded siblings from the analysis.

The current study is limited because parental report of their child's diet may not be as accurate as possible due to the limited ability of adults to know what their child(ren) eat while away from home (i.e. at daycare or a friends house). The study is also limited in its generalizability. The study population consisted of Caucasian and Native American children, and therefore needs to be validated in other populations to improve the generalizability of the HFFQ. Although, it should be noted that this analysis demonstrates that there is no difference between the reliability of the HFFQ in estimating the dietary intake of two very different populations. Research might also evaluate the contribution of meals consumed while a child is not under parental supervision (e.g., in day care) on total diet intake and diet quality.

In conclusion, the Harvard Service Food Frequency Questionnaire is a simple, self-administered

Table I. Energy and Nutrient Intake and Pearson Correlation Coefficients Quantitated During the Administration of Two Food Frequency Questionnaires and Three 24-hr Dietary Recalls in a Sample of 233 Children Aged 1 to 5 Years

	Energy & Nutrient Intake		Correlations
	Recalls	Harvard Service FFQ	3 recalls and average of 1st and 2nd FFQs[a]
Nutrients and energy	Mean (*SD*)[b]	Mean (*SD*)	N/A
Energy (kcal)	1684 (467)	1688 (482)	N/A
Protein (g)	63 (17)	69 (20)	0.43
Carbohydrate (g)	217 (66)	204 (60)	0.52
Sucrose (g)	36 (17)	23 (10)	0.59
% Fat	34 (5)	37 (4)	N/A
Total fat (g)	65 (21)	69 (23)	0.62
Cholesterol (mg)	222 (107)	250 (99)	0.48
Dietary fiber (g)	11 (4)	12 (4)	0.26
Vitamin A (RE)	1035 (569)	1176 (449)	0.49
Vitamin E (mg)	8 (5)	10 (7)	0.56
Vitamin C (mg)	117 (66)	114 (49)	0.58
Vitamin B1 (mg)	2 (1)	2 (1)	0.57
Vitamin B2 (mg)	2 (1)	3 (1)	0.56
Niacin (mg)	19 (8)	21 (8)	0.55
Folate (ug)	274 (133)	307 (147)	0.55
Vitamin B6 (mg)	2 (1)	2 (1)	0.58
Vitamin B12 (ug)	5 (3)	6 (2)	0.47
Calcium (mg)	1016 (328)	1087 (319)	0.60
Zinc (mg)	10 (7)	11 (5)	0.31
Magnesium (mg)	225 (69)	220 (60)	0.63
Iron (mg)	14 (6)	12 (6)	0.51
	Average correlations		
All childen (n = 233)			0.52
1 through 2 year olds (n = 129)			0.51
3 to 5 year olds (n = 104)			0.49
Native American (n = 131)			0.51
Caucasian (n = 102)			0.49

[a]Pearson Correlation coefficients adjusted for energy intake and within person variation.
[b]*SD,* standard deviation.

questionnaire completed by the child's parent or guardian that is useful in assessing the diets of Native American and Caucasian children. It may also provide important nutritional information about this age group for future program planning, research, education, and intervention purposes.

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